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The Emotiv EPOC interface paradigm in Human-Computer Interaction

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Abstract. Numerous studies have suggested the use of decoded error potentials in the brain to improve human-computer communication. Together with state-of-the-art scientific equipment, experiments have also tested instruments with more limited performance for the time being, such as Emotiv EPOC. This study presents a review of these trials and a summary of the results obtained. However, the level of these results indicates a promising prospect for using this headset as a human-computer interface for error decoding.

1 The Emotiv EPOC interface

Emotiv EPOC is a new portable, multichannel Brain-Computer-Interface (BCI), with high resolution, intended for research practice in assistive technology. Somewhat, the evolution of this device capable of deciphering brain processes that can handle virtual or real objects, resembles that of the Wii Balance Board platform originally used as a controller for Nintendo video games and then as a medical tool to rehabilitate people with balance problems.

Although it has been designed for computer games, today the EPOC interface suggests numerous experiments on commanding an external device with a thoughtful intention.

Designed as a piece of equipment combining two parts, one hardware and one software, the EPOC interface is essentially capable of decoding the bioelectric brain activity, analyzing it using a specialized algorithm, and then transmitting a command to a computer.

The hard drive requires a headset (Figure 1) with 14 sensors capable of detecting and recording electrical potentials from scalp level in real time in the form of an electroencephalogram. The software

Fig.1. Emotiv EPOC.

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attached to the device provides, some flexibility in, viewing the recorded data stream in EEGLAB format, monitoring the contact area quality, automatic or manual scaling of the desired channel, inserting timed markers that can be stored in the data stream, and analyzing of specific signals (FFT).

There are currently 76 companies building equipment and programs for BCI interfaces. Certainly, recent attempts to commercialize such viable devices (Intendix - Austria, 2012; Emotiv - USA, 2009; Cyberlink Brainfingers - USA; 1995; BioSemi "Pin-type"-Netherland, 1998) only support investment in the future development efforts of such systems.

The impact of this interface may be, primarily, clinical. Its effects would manifest itself directly on people with neuromuscular disabilities or neurodegenerative diseases, for which there is no other treatment. For these patients, it represents, in this way, an alternative to natural communication or by neuromuscular pathways, via an artificial bypass.

2 Emotiv epoc headset in human-computer interaction

The past few years have marked remarkable performance in the development of computer science applications in medicine. Among them, the new BCI interface for direct communication between the human brain and an external device has inspired numerous research into signal processing and computer learning by translating thought processes.

Experiments realized by Lievesley and others [1] in 2011, demonstrate that Emotiv EPOC can be used as a communication interface with a computer that, in turn, could control a neuroprotective device. There were, in fact, 2 projects that started from the following assumptions:

1. The EPOC interface transfer rate would be superior to that of a system of two head-operated switches attached to the headrest of an wheelchair which could be operated by left-right movements of the head (thus simulating the way of communication of a person with disabilities);
2. A virtual object could be moved on the computer screen using neurophysiological signals reflecting cognitive state.

The first hypothesis was tested by detecting facial expressions from the perception of specific tasks simulated on a computer. When using head-operated switches, the success rate was 100% while in case of the interface 73.3%. The same ratio was also obtained for the reaction time, 0.74 s versus 1.03 s with Emotive EPOC while a significantly higher one was displayed, in favour of the switches, in the deduction of the transfer rate of 1.38 b/s compared to 0.57b/s (0.44 - 2.66 b/s being the limits of the values obtained in other studies so far). Although the differences were not significant in all situations, the findings contradicted the initial hypothesis (provided the subjects were able to move his neck).

Not the same thing resulted from the run of the second experiment. Here, the participants used their thoughts to control, the image of a cube on a display, which could be moved "away" when the subject thought "push" or would remain in a static position during "neutral" EEG activity.

The success rate was about 79% in the absence of a threshold time and much higher, about 96%, in its presence. The data transfer was performed at a minimum rate of 0.65 mb/s and a maximum of 65 mb/s (the transfer rates identified in previous research averaged 60 mb/s for devices employing cortical potentials and 10 mb/s achieved by those applying sensorimotor rhythms).

Evaluating these results, it can be said that despite the lower transfer rates compared to other instruments for scientific use that measure EEG or cortical potentials (but which are, on the other hand, more impractical and also more expensive), and in the absence of a more accessible alternative, the Emotive interface EPOC shows a real potential for assistive technology.

The EPOC system has also been successfully used to measure the response of cortical response to auditory stimulation (evoked potential, P_3 component) [2, 3] and visual stimulation [3, 4]. The results indicated a high accuracy for ERP (event-related potential or evoked potential) peaks, ie. P_1, N_1, P_2, N_2 and P_3, but not for the MMN component (mismatch negativity).

In 2013, Badcock and others [5] adapted the Emotiv EPOC interface to the recording of evoked potentials by auditory stimuli (peaks P_1, N_1, P_2, N_2 and P_3) in adults and later, in 2014, in children (differences between these groups being given by the different levels of cortical and cognitive development). They have tested, in this way, the likeness of the waveforms of a professional system with those of an Emotive EPOC interface and have demonstrated through their results their similarity in morphology, amplitude and latency.

Taken together, the results of these studies suggest the validity and reliability of the EPOC interface to measure evoked potentials and EEG activity. It also opens new research paths, because it can, in principle, be used anywhere (for example, schools, homes, shopping centres, hospitals). The fast configuration procedure, portability, simple use and, last but not least, the price, gives the interface the status of a promising instrument for measuring electrical signals generated in the brain.

3 The evoked potentials

Environmental stimuli trigger distinct neuronal responses (evoked potentials or ERPs) in the human brain that can be measured, for example, by an electroencephalogram (EEG). An external action can be a stimulus for the subject who perceives it, triggering the triggering of evoked potentials. If, in a particular way, the action should, from the perspective of the subject, no longer continue or return to an earlier stage, the potential evoked takes the form of an error-related potential or ErrP.

The error potential (ErrP) is basically a particular case of evoked potential. The perception of an error can be recorded using the encephalogram as a distinct neural signal [6]. It appears in the brain automatically, involuntarily, without previous training of the subject. Although physiologically, the response mechanism of the brain to the perception of an error is complex and involves more brain areas, it has basically been demonstrated that the response to an error can be detected [7] in the anterior medial frontal cortex (pMFC).

Research of recent years highlights the fact that these error signals can be effectively used in human-computer communication and BCI applications [8, 9, 10]. Such a signal can also be used to reduce the possibility of returning an error through the system's ability to self-correct "by learning from its own fault" [11, 12].

Eric W. Sellers and others [13] present, in 2010, an interface that allows people with disabilities, including also serious cases to move a cursor on a display using the signals extracted from the sensory motor cortex.

In 2014, Chavarriaga and others [14] use a BCI interface that measures the response of the brain to a stimulus produced by the recognition of an error, to correct an action. The idea is taken over in 2015 by Ehrlich and Cheng [15] which validate an objective method of correcting an error by detecting signals resulting from the perception of the inaccuracy / correctness of a bivalent task performed by a robot. Their result confirms previous reports and demonstrates that robot action can be detected and modelled from EEG signals with an accuracy of approximately 70%. Frank and others, Hajcak and others [16, 17], in 2005, Taylor et al [18], in 2007, and then Chavarriaga and others [14], in 2014, describe the shape of these signals and their latency from the onset of the stimulus, and demonstrate that their amplitude depends on the following factors: the subject's grasp on the relevance of the task,

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the degree of involvement of the subject in the task (the amplitude of the signal is lower if the subject passively follows an external device than if it controlled this device) as well as the frequency of stimuli.

Ferrez and Millán [9], in 2008, Chavarriaga and Millán [19], in 2010, confirm that the ErrP signals are stable over time, that their shape is somewhat maintained for repeated measurements after an indefinite period of time - one year, for example - and then their triggering does not depend on the type of task but rather on the perception of incorrectness.

The form of error signals is also influenced by pathological and subject-specific conditions [20]. They reappear, demonstrated in another study, in the same form upon repetition of stimuli [21] regardless of the nature of the tasks [22].

An evoked potential triggered by a particular stimulus takes the form of the signal in Figure 2. It is characterized by a positive peak at about 100 ms from the onset of the stimulus, followed by a negative deviation at 260 ms (250 ms).

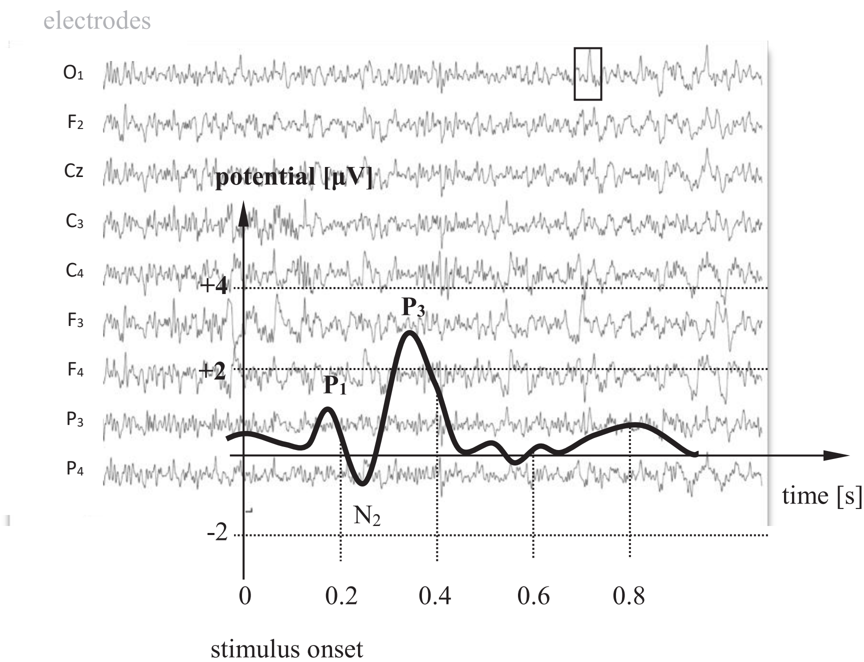

Fig. 2. Event-related potential (electrode O_1).

A second, more pronounced positive peak occurs at around 330 ms after the stimulus [19]. Although they come from the same sources as an EEG, the evoked potentials are much smaller than these (up to about 5 µV, while EEG waves can reach 50 µV). Therefore, they cannot be routinely distinguished over the background of an EEG record with the naked eye, being covered by surrounding, much larger signals. To emphasize the former, it is necessary to sum up, filter and mediate EEG signals so that the regularity of the signal background is distinguished.

ErrP is recognized in a record by negative signal deflection (ERN) immediately after triggering the stimulus in the alpha frequency in the frontal-centre area (Figure 3). The ERN component, consistently associated with conflict cases (such as incongruent stimuli), is followed by a positive deviation that reaches a maximum value at about 400 ms, called error positivity or P_e, and attributed by specialists to error awareness processing .

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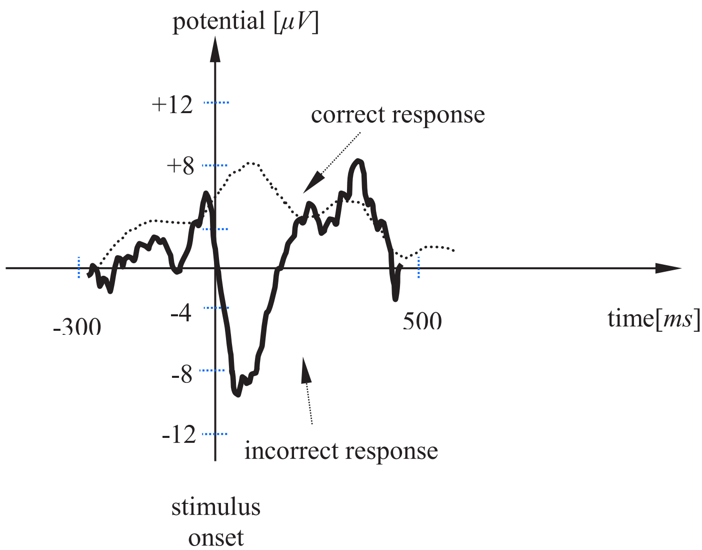

Fig. 3. The shape of the signal after the correct and incorrect response (electrode FC_z).

ErrP integration into human-computer interaction systems involves two key factors: detecting the error in single-trial basis and using this information to modify the online process. But practical applications of neurological measurements, pursuing the initial purpose of these researches, should take into account the performance of the system and its applicability to people with disabilities or neurodegenerative diseases.

4 Conclusions

The potential of the EPOC Emotive set for the acquisition and analysis of EEG signals has already been confirmed by numerous studies.

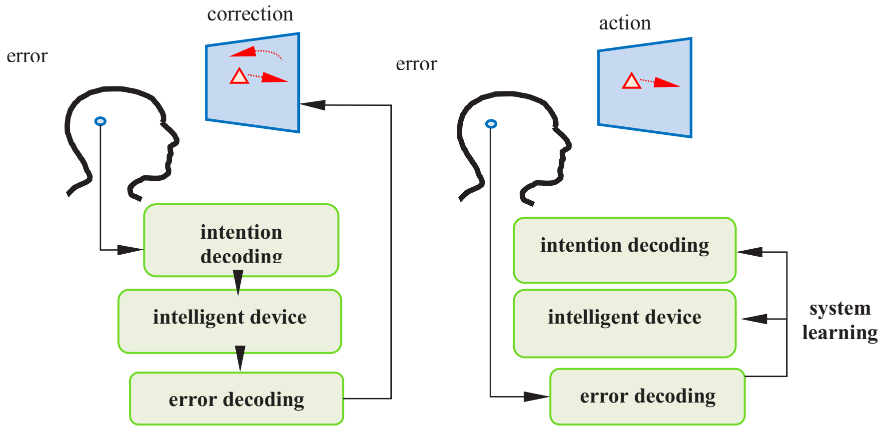

Fig. 4. Use of error-related potentials to improve BCI performance. Left: erroneous actions is used to trigger a corrective action; Right: error is used to update the BCI classifier and reinforce the learning.

While exhibiting lower transfer rates and accuracy, the results were still encouraging, particularly in view of the versatility and practicability of the device.

The work revised in this paper supports the feasibility of decoding potential errors using the Emotive EPOC interface and their use to improve the performance of human-computer communication systems. There is solid evidence that ErrPs can be successfully detected on a single-trial basis and that they can be effectively used in both HCI and BCI applications. The possibility of detecting potential errors can be used to deduce the optimal behaviour of performing bivalent tasks that will then allow the output data to be adapted to a controllable human-computer environment (Figure 4).

The use of BCI opens up many perspectives in a vast interdisciplinary field that brings together neurology, electrical engineering, prosthetics, psychology and computer science. Among these, the latest applications integrate, first of all, health and education.

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